WHAT IS CLAIMED IS:

1   1. A magnetoresistive head comprising:

2   an antiferromagnetic layer;

3   a pinned layer formed on the antiferromagnetic layer with a magnetizing

4   direction of the pinned layer being fixed;

5   a nonmagnetic layer formed on the pinned layer;

6   a free layer formed on the nonmagnetic layer;

7   a magnetic domain control film for magnetic domain control of the free layer;

8   and a pair of electrode films for supplying electric current to a stack of the

9   antiferromagnetic layer, the pinned layer, the nonmagnetic layer, and the free layer;

10   wherein, when a width of the free layer as viewed from an air bearing surface

11   is defined as a geometrical track width Twr_geo(nm) and expressed as x, a magnetization

12   film thickness product Br•t(G•μm) of the magnetic domain control film and x satisfy the

13   following:

14   $-2.94 \cdot 10^{-4}x^3 + 8.54 \cdot 10^{-2}x^2 - 5.73x + 116 \leqq Br \cdot t < 3.75 \cdot 10^{-1}x + 130$ and $40 \leqq x < 160$.

1   2. A magnetoresistive head comprising:

2   an antiferromagnetic layer;

3   a pinned layer formed on the antiferromagnetic layer with a magnetizing

4   direction of the pinned layer being fixed;

5   a nonmagnetic layer formed on the pinned layer;

6   a free layer formed on the nonmagnetic layer;

7   a magnetic domain control film for magnetic domain control of the free layer;

8   and

9   a pair of electrode films for supplying electric current to a stack of the

10   antiferromagnetic layer, the pinned layer, the nonmagnetic layer, and the free layer;

11   wherein, when a width of the free layer as viewed from an air bearing surface

12   is defined as a geometrical track width Twr_geo (nm) and expressed as x, a magnetization

13   film thickness product Br•t(G•μm) of the magnetic domain control film and x satisfy the

14   following:

15   $-2.94 \cdot 10^{-4}x^3 + 8.54 \cdot 10^{-2}x^2 - 5.73x + 116 \leqq Br \cdot t \leqq -2.94 \cdot 10^{-4}x^3 + 8.54 \cdot 10^{-2}x^2 - 5.73x +$

16   141, $Br \cdot t < 3.75 \cdot 10^{-1}x + 130$, and $40 \leqq x < 160$.

1   3. A magnetoresistive head comprising:

2   an antiferromagnetic layer;

3   a pinned layer formed on the antiferromagnetic layer with a magnetizing

4 direction of the pinned layer being fixed;

5   a nonmagnetic layer formed on the pinned layer;

6   a free layer formed on the nonmagnetic layer;

7   a magnetic domain control film for magnetic domain control of the free layer;

8 and

9   a pair of electrode films for supplying electric current to a stack of the

10 antiferromagnetic layer, the pinned layer, the nonmagnetic layer, and the free layer;

11   wherein, when a width of the free layer as viewed from an air bearing surface

12 is defined as a geometrical track width Twr_geo(nm) and expressed as x, a magnetization

13 film thickness product $Br{\cdot}t(G{\cdot}\mu m)$ of the magnetic domain control film and x satisfy the

14 following:

15   $-2.94{\cdot}10^{-4}x^3 + 8.54{\cdot}10^{-2}x^2 - 5.73x + 151 \leqq Br{\cdot}t < 3.75{\cdot}10^{-1}x + 165$ and $40 \leqq x < 160$.

1   4. A magnetoresistive head comprising:

2   an antiferromagnetic layer;

3   a pinned layer formed on the antiferromagnetic layer with a magnetizing

4 direction of the pinned layer being fixed;

5   a nonmagnetic layer formed on the pinned layer;

6   a free layer formed on the nonmagnetic layer;

7   a magnetic domain control film for magnetic domain control of the free layer;

8 and

9   a pair of electrode films for supplying electric current to a stack of the

10 antiferromagnetic layer, the pinned layer, the nonmagnetic layer, and the free layer;

11   wherein, when a width of the free layer as viewed from an air bearing surface

12 is defined as a geometrical track width Twr_geo(nm) and expressed as x, a magnetization

13 film thickness product $Br{\cdot}t(G{\cdot}\mu m)$ of the magnetic domain control film and x satisfy the

14 following:

15   $-2.94{\cdot}10^{-4}x^3 + 8.54{\cdot}10^{-2}x^2 - 5.73x + 151 \leqq Br{\cdot}t \leqq -2.94{\cdot}10^{-4}x^3 + 8.54{\cdot}10^{-2}x^2 - 5.73x +$

16   $176, Br{\cdot}t < 3.75 {\cdot} 10^{-1}x + 165$, and $40 \leqq x < 160$.

1   5. A magnetoresistive head comprising:

2   an underlying layer;

3   a free layer formed on the underlying layer;

4   a magnetic domain control film for magnetic domain control of the free layer;

5   a nonmagnetic layer formed on the free layer;

6   a pinned layer formed on the nonmagnetic layer with a magnetizing direction

7 of the pinned layer being fixed;

8   an antiferromagnetic layer fixing magnetization of the pinned layer; and

9   a pair of electrode films for supplying electric current to a stack of the

10 underlying layer, the free layer, the nonmagnetic layer, the pinned layer and the

11 antiferromagnetic layer;

12   wherein, when a width of the free layer as viewed from an air bearing surface

13 is defined as a geometrical track width Twr_geo(nm) and expressed as x, a magnetization

14 film thickness product $Br{\cdot}t(G{\cdot}\mu m)$ of the magnetic domain control film and x satisfy the

15 following:

16 $-2.94{\cdot}10^{-4}x^3 + 8.54{\cdot}10^{-2}x^2 - 5.73x + 116 \leqq Br{\cdot}t < 3.75{\cdot}10^{-1}x + 130$ and $40 \leqq x < 160$.

1   6. A magnetoresistive head comprising:

2   an underlying layer;

3   a free layer formed on the underlying layer;

4   a magnetic domain control film for magnetic domain control of the free layer;

5   a nonmagnetic layer formed on the free layer;

6   a pinned layer formed on the nonmagnetic layer with a magnetizing direction

7 of the pinned layer being fixed;

8   an antiferromagnetic layer fixing magnetization of the pinned layer; and

9   a pair of electrode films for supplying electric current to a stack of the

10 underlying layer, the free layer, the nonmagnetic layer, the pinned layer and the

11 antiferromagnetic layer;

12   wherein, when a width of the free layer as viewed from an air bearing surface

13 is defined as a geometrical track width Twr_geo(nm) and expressed as x, a magnetization

14 film thickness product $Br{\cdot}t(G{\cdot}\mu m)$ of the magnetic domain control film and x satisfy the

15 following:

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16   $-2.94 \cdot 10^{-4}x^3 + 8.54 \cdot 10^{-2}x^2 - 5.73x + 116 \leqq Br \cdot t \leqq -2.94 \cdot 10^{-4}x^3 + 8.54 \cdot 10^{-2}x^2 - 5.73x +$

17   $141, Br \cdot t < 3.75 \cdot 10^{-1}x + 130,$ and $40 \leqq x < 160.$

1   7. A magnetoresistive head comprising:

2   an underlying layer;

3   a free layer formed on the underlying layer;

4   a magnetic domain control film for magnetic domain control of the free layer;

5   a nonmagnetic layer formed on the free layer;

6   a pinned layer formed on the nonmagnetic layer with a magnetizing direction

7   of the pinned layer being fixed;

8   an antiferromagnetic layer fixing magnetization of the pinned layer; and

9   a pair of electrode films for supplying electric current to a stack of the

10   underlying layer, the free layer, the nonmagnetic layer, the pinned layer and the

11   antiferromagnetic layer;

12   wherein, when a width of the free layer as viewed from an air bearing surface

13   is defined as a geometrical track width Twr_geo(nm) and expressed as x, a magnetization

14   film thickness product $Br \cdot t(G \cdot \mu m)$ of the magnetic domain control film and x satisfy the

15   following:

16   $-2.94 \cdot 10^{-4}x^3 + 8.54 \cdot 10^{-2}x^2 - 5.73x + 151 \leqq Br \cdot t < 3.75 \cdot 10^{-1}x + 165$ and $40 \leqq x < 160.$

1   8. A magnetoresistive head comprising:

2   an underlying layer;

3   a free layer formed on the underlying layer;

4   a magnetic domain control film for magnetic domain control of the free layer;

5   a nonmagnetic layer formed on the free layer;

6   a pinned layer formed on the nonmagnetic layer with a magnetizing direction

7   of the pinned layer being fixed;

8   an antiferromagnetic layer fixing magnetization of the pinned layer; and

9   a pair of electrode films for supplying electric current to a stack of the

10   underlying layer, the free layer, the nonmagnetic layer, the pinned layer and the

11   antiferromagnetic layer;

12   wherein, when a width of the free layer as viewed from an air bearing surface

13   is defined as a geometrical track width Twr_geo(nm) and expressed as x, a magnetization

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14 film thickness product Br•t(G•μm) of the magnetic domain control film and x satisfy the

15 following:

16 $-2.94 \cdot 10^{-4}x^3 + 8.54 \cdot 10^{-2}x^2 - 5.73x + 151 \leq$ Br•t $\leq -2.94 \cdot 10^{-4}x^3 + 8.54 \cdot 10^{-2}x^2 - 5.73x +$

17 176,

18 Br•t $< 3.75 \cdot 10^{-1}x + 165$, and $40 \leq x < 160$.

1   9. A magnetoresistive head comprising:

2   an insulative layer formed on a substrate;

3   an antiferromagnetic layer formed on the insulative layer;

4   a pinned layer formed on the antiferromagnetic layer with a magnetizing

5 direction of the pinned layer being fixed;

6   a nonmagnetic layer formed on the pinned layer;

7   a free layer formed on the nonmagnetic layer;

8   a pair of electrode films for supplying electric current to a stack of the

9 antiferromagnetic layer, the pinned layer, the nonmagnetic layer and the free layer; and

10   an electrode underlying film;

11   wherein the electrode underlying film is formed directly on the insulative film

12 in a case where a width of the free layer as viewed from an air bearing surface is defined as

13 Twr_geo (nm) and expressed as x, and x < 40.

1   10. A magnetoresistive head according to any one of claims 1 to 8, wherein

2 the magnetic domain control film comprises a magnetic film made of a CoPt alloy

3 comprising at least 4 to 30 at% of Pt, or a CoCrPt alloy, or $CoCrPt-ZrO_2$ or $CoCrPt-SiO_2$

4 further comprising 2 to 15 at% of Cr.

1   11. A magnetoresistive head according to any one of claims 1 to 8, wherein

2 the magnetic domain control film comprises a stacked film in which at least two or more

3 magnetic films are antiferromagnetically coupled by way of a nonmagnetic film comprising

4 Ru, Cr, Ir, Rh, Os, Re, Au, Ag, Cu or an alloy thereof, and a magnetic film as a constituent

5 element thereof is a magnetic film comprising a CoPt alloy comprising at least 4 to 30 at% of

6 Pt, or a CoCrPt alloy, or $CoCrPt-ZrO_2$ or $CoCrPt-SiO_2$ further comprising 2 to 15 at% of Cr

7 or a magnetic film having soft magnetic property containing Fe or Ni.

1   12. A magnetoresistive head according to any one of claims 1 to 8, wherein

2 the magnetic domain control film is a stacked film having two-layers of magnetic films

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3   antiferromagnetically coupled by way of a nonmagnetic film, and the magnetization film

4   thickness product Br•t of the magnetic domain control film is defined as

5   Br•t = Br1•t1 - Br2•t2

6   assuming residual magnetic flux densities of the two layers of magnetic layers as Br1 and

7   Br2, respectively, and film thicknesses thereof as t1 and t2, respectively.

1   13. A magnetoresistive head according to any one of claims 1 to 8, wherein

2   the magnetic domain control film is a stacked film having three layers of magnetic films and

3   antiferromagnetically coupled by way of a nonmagnetic film, and the magnetization film

4   thickness product Br•t of the magnetic domain control film is defined as

5   Br•t = Br1•t1 - Br2•t2 + Br3•t3

6   assuming residual magnetic flux densities of the three magnetic layers as Br1, Br2, and Br3,

7   respectively, and the film thicknesses thereof as t1, t2, and t3, respectively.

1   14. A magnetic head having a magnetoresistive head according to any one of

2   claims 1 to 8 having as a reading head and having a writing head for in-plane recording.

1   15. A magnetic head having a magnetoresistive head according to any one of

2   claims 1 to 8 as a reading head and having a writing head for perpendicular recording.

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